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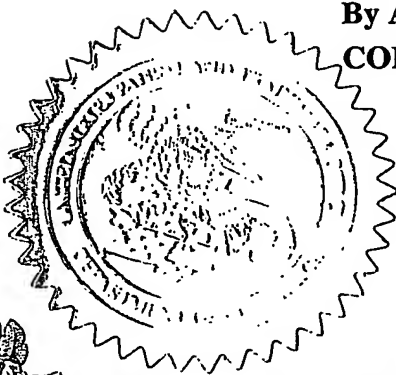
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APPLICATION NUMBER: 60/510,145

FILING DATE: October 14, 2003

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This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

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ENCLOSED APPLICATION PARTS (check all that apply)					
<input checked="" type="checkbox"/> Specification		Number of Pages 19		<input type="checkbox"/> CD(s), Number	
<input checked="" type="checkbox"/> Drawing(s)		Number of Sheets 9		<input type="checkbox"/> Other (specify)	
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Respectfully submitted,

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10/14/03

REGISTRATION NO.

25,505

(if appropriate)

Docket Number:

66386-0335

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P19LARGE/REV05

Microphone Preamplifier

This invention relates to a microphone preamplifier and a microphone module.

5 Introduction

The preferred type of microphone for telecom applications (ie Mobile phones) has for many years been electret microphones. This type of microphone is based on the principle of a capacitor, which is formed by a movable member that constitutes a membrane of the microphone and another member, eg a
10 so-called back plate of the microphone. This microphone, which constitutes the capacitor, is charged by a constant electrical charge.

A sound pressure detected by the microphone will cause the membrane to move and consequently change the capacitance of the capacitor formed by
15 the membrane member and the other member. If the charge on the capacitor formed by these two members is kept constant, then the voltage across the two capacitor members will vary with the incoming sound pressure level. As the charge on the microphone capacitor has to be kept constant it is important not to load the microphone capacitance with any resistive load
20 since this will discharge the capacitor. Therefore, a buffer/amplifier with a high input resistance has to be connected to the microphone capacitance. The input resistance of this amplifier has to be extremely high – in the magnitude of Giga ohms. Also the input capacitance of this amplifier has to be very small in order to achieve a high sensitivity.

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For many years this buffer/preamplifier has been implemented as a simple JFET. For many reasons microphones for telecom use are becoming smaller and at the same they should be more sensitive. This is due to market trends which encompass eg hands free operation of different types of equipment
30 and camera/video applications.

This yields a contradiction since sensitivity of the microphone drops as size goes down. Additionally, the capacitance of a microphone becomes lower with size. All other things being equal, this will further reduce the sensitivity of the microphone and the buffer in combination.

5

Today telecom microphones typically have a sensitivity of -40dBV and a capacitance of 7pF. This capacitance is also denoted the cartridge capacitance. The term 'cartridge' is used to designate the microphone without the preamplifier. The vast majority of JFETs for this purpose have an input capacitance of approximately 5-7pF. Comparing this input capacitance to the cartridge capacitance it can be deduced that half of the signal is lost before it is being amplified.

15 Telecom microphones with an integrated preamplifier are sold in high volumes and at very low prices. As cost of an amplifier for a telecom microphone is directly related to the size of the preamplifier chip die it is important, for the purpose of reducing price, that the preamplifier die is as small as possible.

20 So obviously, there is a need for microphone preamplifiers with gain and very low input capacitance, and lowest possible preamplifier die area. Additionally, low noise is important. Low noise is important as noise can be traded for area – ie if the circuit has low noise and a noise lower than required then this can be used to design the preamplifier with a lower die area and thus lower cost.

25 CMOS microphone preamplifiers have proven superior to JFET microphone preamplifiers in recent years as since they can be designed with lower noise, lower input capacitance and at the same time with more functionality such as gain etc. In hearing aids, microphone preamplifiers are exclusively designed in CMOS. The reason for this is that CMOS amplifiers designed in CMOS

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technology provides signal to noise ratios far beyond what can be reached by amplifiers implemented in JFET technology. This applies in particular when the cartridge capacitance is very low.

- 5 When designing a preamplifier in CMOS technology for a microphone there is normally three noise sources. These sources are noise from a bias resistor, $1/f$ noise from an input transistor, and white noise from the input transistor. We assume that input transistor noise dominates. Both white noise and $1/f$ noise can be minimized by optimizing the length and the width of the input transistor(s). This applies for any input stage eg a single transistor stage or a differential stage. The noise from the bias resistor can also be minimized. If the bias resistor is made very large then the noise from the resistor will be high pass filtered and the inband noise will be very low. This has the effect though that the lower bandwidth limit of the amplifier will be very low. This can be a problem as the input of the amplifier will settle at a nominal value only after a very long period of time after power up. Additionally, signals with intensive low frequency content arising from eg slamming of a door or infra sound in a car can overload the amplifier. Another related problem is small leakage currents originating from mounting of the die inside a microphone module. Such currents will due to the extreme input impedance establish a DC offset. This will reduce the overload margin of the amplifier.

25 Related art

On the one hand, several solutions have been proposed using preamplifiers based on JFET or other technologies. However, these solutions do inherently have a relatively high noise level. Consequently, the prior art solutions can not be designed for smallest possible die area.

On the other hand, in hearing aid microphones the problem of excessive sensitivity to infrasound is handled by using a buffer amplifier as input stage and then high-pass filtering the output of the buffer amplifier. After the signal has been high-pass filtered it doesn't contain the large low frequency components which could overload the amplifier and it can then be further amplified. This approach has proven to work well with hearing aid microphones where the cartridge sensitivity is relatively high - eg 20mV/Pa.

For telecom microphones the cartridge sensitivity is normally around 5-7mV/Pa. And for new types of applications require a sensitivity of as much as 40mV/Pa. Also here the approach from hearing aids would work fine but for telecom applications also the area of the device is important as this relates directly to cost of the device. The two stage solution has two disadvantages; as it has two stages, it is noisier and because there is no gain in the first stage the physical size of the high pass filter has to be relatively large. The size of the filter could be minimized by increasing the gain of the first stage but then the amplifier would overload because of low frequency components. I.e. The function of the filter is to remove these components before amplification. Thus the solution originally developed for hearing aid microphones will be far from optimal for the new high sensitive telecom microphones. The area of the amplifier die would simply be too large and the device consequently too costly.

Thus to conclude, the demand for smaller microphones and consequently the application of smaller microphones results in a smaller microphone capacitance. This will increase the spectral density of noise within the audible range. Therefore a larger bias resistor is required to compensate for the otherwise increased noise density in the audible range.

The demand for a large input bias resistor requires a small input leakage current. Such a small input leakage current can only be obtained by CMOS

technology. In order to achieve a good signal-to-noise ratio, CMOS technology combined with a bias resistor larger than 10 GOhm is preferred. In hearing aid applications the above is provided by a simple 0-dB buffer in CMOS technology combined with a large bias resistor. This will provide a feasible design since the sensitivity of microphones for hearing aid applications generally is relatively high.

However, since sensitivity is traded for low price, microphones for telecommunications purpose are less sensitive. From a market perspective, there is a demand for a larger sensitivity of the microphone and preamplifier in combination. So, therefore the gain in the preamplifier is to be increased to meet the demand. Additionally, there is a demand for low noise in the audible range. Moreover, in order to ensure a good signal-to-noise ratio while meeting the demand for a relatively large sensitivity, the input capacitance of the preamplifier must be small to avoid an unnecessary signal loss from the microphone (cf. the equivalency of the microphone signal being exposed to a voltage divider constituted by the capacitances).

Since, the chip area the preamplifier occupies must be as small as possible to obtain a relatively low cost price the preamplifier must be as small as it can be. Therefore, since amplifier configurations known from hearing aids are generally not optimised for chip space to the same extent, these configurations are not applicable. Further, the microphone element is much less sensitive for telecom applications.

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Summary of the invention

The solution is to design a preamplifier with a single gain stage which has a low gain for low frequency signals and has a high gain for audio band signals.

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As the total sensitivity of the new types of telecom microphones are very high, the output signal swing of the microphone can become very large; eg about 1Vpp, which is far beyond what seen previously in both telecom and hearing aid market. The fact that the telecom microphone has to be operated with two terminals (combined out and power) makes the design for a large maximum output signal swing even more difficult. This calls for solutions different from hearing aid applications.

It is an objective of the present invention to provide a preamplifier with the lowest possible input capacitance, lowest possible noise, largest output signal swing in a two terminal configuration and at the same time exhibiting the lowest smallest possible die area.

Also it is an objective of the present invention to provide a preamplifier having a large power supply rejection, low distortion in a two terminal configuration.

It is an objective of the present invention to provide an amplifier which is able to handle slowly varying signals with relatively large amplitude at its input terminal while at the same time being able to amplify a low level signal with a higher frequency without distortion.

It is an objective of the present invention to provide an amplifier which performance is very insensitive towards leakage and parasitics connected to the input.

The invention relates, in a first aspect, to a microphone preamplifier which provides an output signal in response to an input microphone signal and an input feedback signal obtained by filtering the output signal with a filter.

The intrinsic sensitivity of telecom ECM's are normally relatively low. As a consequence of this the preamplifier for a telecom ECM requires gain.

Furthermore the telecom market today requires even higher sensitivity than before. The consequence of this is that even higher gain from the preamplifier is required. But still the same overload margin is required. Also the ability to handle large low frequency signals such as car rumbling and door slamming should be the same. Ideally the amplifier should have a large gain at the frequency band of interest. E.g. 20Hz to 10kHz. And a low gain at all other frequencies. For feedback amplifiers the loopgain directly relates to the quality of the amplification. Here, it should be noted that the loopgain is roughly inversely proportional to the overall gain characteristic. By quality is meant low distortion etc. So an amplifier with a large loopgain outside the bandwidth of interest will give rise to very little distortion in this frequency range. But more importantly, intermodulation distortion introduced by frequency components outside the frequency band of interest eg low frequencies will be very low. Low frequencies in fact also include DC offset levels introduced by parasitic leakage currents introduced by the packaging or the mounting of the IC inside the microphone can. The filter can be implemented as a purely passive filter or as an active implementation.

CMOS preamplifiers for capacitive microphones normally have three noise sources. The first two are $1/f$ noise and whitenoise from CMOS devices in the amplifier (for a well designed amplifier it will be the input devices). The third one is low pass filtered white noise from the bias device connected to the input. This bias device sets the dc bias level of the input. As the device is connected to a capacitive source (the microphone) then the noise will be low pass filtered. If we assume that the noise is white, which is a good assumption then it can be shown that the total noise power is KT/C . Where K is boltzmanns constant, T temperature in Kelvin and C the capacitance connected to the node which normally equals the microphone capacitance. So as the trend goes for smaller microphones cartridges with lower cartridge capacitance then this noise source will increase when the microphone cartridge capacitance decreases. The the total noise power coming from the

low pass filtered white noise in the frequency band of interest will though also depend on the cutoff frequency of the the lowpass filter. I.e. The low the cutoff frequency the smaller a portion of the total noise power will be inside the frequency band of interest. So if the microphone capacitance is lower
 5 then the impedance of the bias device will have to be increased in order to keep the noise low. Roughly the impedance will have to be increased by a factor 4 each time the capacitance is decreased by a factor 2.

There are several ways of implementing the high impedance device. Many different devices can be used and has been. E.g. Diodes, MOS transistors,
 10 bipolars etc. and even more complex circuits have been used. Most devices are not symmetrical and thus they will exhibit a much larger impedance when biased in one direction. E.g. A single diode. In fact the very large impedance is only desirable for a very narrow voltage range around zero. Normally 100-200mV is only needed. If the impedance is very at even at signal levels
 15 beyond 200mV then large low frequency signal will pass directly to the input of the preamplifier. This will be the case if by example a single diode is used to bias the input. I.e. In the reverse bias region of the diode the impedance is extremely large even up to the breakdown voltage of the diode which might be as high as 10V. On the other hand in forward bias the impedance of the
 20 diode reduces dramatically above 400mV. By coupling two diodes in a antiparallel coupling it is assured that the signal is limited by the transfer characteristic of the two diodes combined before entering the preamplifier. This assures that very large signals do not overload the preamplifier for several minutes. I.e. Refer to the very large timeconstants. And at the same time the
 25 impedance around zero is very large assuring very low noise. But many other devices or combination of devices can be used as long as they have a symmetrical voltage current characteristic and a very large impedance around zero.

Brief description of the drawings

- fig. 1 shows a source-follower coupled to a microphone and illustrates noise sources in a microphone amplifier;
- fig. 2 shows the spectral noise density of the source-follower;
- 5 fig. 3 shows an amplifier according to a first aspect of the invention;
- fig. 4 shows a detailed view of the amplifier in the first aspect;
- fig. 5 shows three embodiments for symmetrical bias resistor input.
- fig. 6 shows an amplifier configuration with RF filters;
- fig. 7 shows an amplifier configuration with DC output level adjustment;
- 10 fig. 8 shows an example of loop gain, feedback filter and overall gain characteristics; and
- fig. 9 shows an amplifier configuration with a voltage pump.

Fig. 1 shows a source-follower coupled to a microphone cartridge element.

15 This circuit is prior art. But as a not very complex circuit it is very useful for explaining the basic function of a microphone preamplifier. This circuit has three significant noise sources; ie noise from the bias resistor, white noise from the PMOS device and $1/f$ noise from the PMOS device. The figure shows a very simple amplifier but all amplifiers have these three significant

20 noise sources.

Fig. 2 shows the spectral noise density of the source-follower. A source follower has been used as an example but the spectral density of the noise will have the same shape for any CMOS amplifier. And the guidelines for

25 optimizing the spectral noise density for best SNR are the same. It can be described how to minimize each component of the spectral noise density. First the bias resistor generated noise. On the figure it can be seen where this component is dominating. I.e. R_{bias} is written in this frequency range. The total noise power coming from the bias resistor can be calculated to kT/C

30 where k is Boltzmann's constant, T is temperature in Kelvin and C is the capacitance connected to the resistor; normally dominated by the

microphone capacitance. On the figure is also shown the A-weighting function and it can be seen that apart from the total noise power of kT/C (which is given by the microphone capacitance) the also the location of the noise has an importance. I.e. if the bias resistor can be made very large then the noise power inside the A-weighting function can be made very small. So the trick is to use a very large bias resistor. From the PMOS device of the source follower originates $1/f$ noise and white noise. This can be made small by increasing the gate area of the device contributing with the noise. By making the device very large both the $1/f$ and the white noise can be reduced to an absolute minimum. The $1/f$ noise can even be reduced to nearly zero using a very large transistor. The consequence of making the transistor very large is though that the signal is damped as the microphone is capacitively loaded. So the transistor should be big but not too big. I.e. an optimum exists for both $1/f$ noise and white noise.

This example shows the noise from a source follower stage but exactly the same argumentation and tradeoffs apply for any CMOS preamplifier for a capacitive source.

Fig. 3 shows an amplifier according to a first aspect of the invention. With the feedback amplifier and a feedback filter having a frequency response with one pole and one zero. The zero is located at a higher frequency than the pole. The filter can be a first order filter or it can be of higher order; eg second order, third order or fourth order. Also it can be implemented as a passive circuit or as an active circuit. The feedback loop assures that the overall gain of the amplifier with feedback is relatively low at low frequencies and relatively high at audio band frequencies. In figure 3 the amplifier is powered from its output terminal. The amplifier is coupled as a non-inverting amplifier with the microphone connected to the positive input. This assures that the capacitive loading of the microphone is very low. I.e. because of the feedback the negative input terminal will exactly follow the positive terminal

and if the input stage of the amplifier is a differential pair then the gate source voltages will remain constant and thus the input capacitance will be very low. A detailed description of one possible embodiment can be seen in figure 4. To set the output DC level of the amplifier a DC offset can be build into the

5 amplifier or even better into the filter. An implementation of an amplifier build in offset is explained in fig. 4. A filter build in DC offset can by example be implemented by inserting a DC current in the filter or by shifting the DC level from the output to the input.

- 10 Fig. 4 shows a detailed view of the amplifier in the first aspect. The amplifier input stage is a differential pair of PMOS devices. This differential pair will have to be optimized in both width and length as an optimum for $1/f$ noise and white noise exists. I.e. see figure 2. If needed, an offset can be built into the differential pair by adjusting the aspect ratio of the two transistors in the
- 15 differential pair. Alternatively or additionally, the mirroring factor of the current mirror in the bottom can be adjusted. If the ratio between the aspect ratio of the differential pair transistors are A and the current mirror factor is B then the offset of the amplifier will be $n \cdot V_t \cdot \ln(A \cdot B)$. An output transistor is connected to the high impedent gain node. The function of this is to ad gain
- 20 and to isolate the high impedant node from the outside. Notice that the only device which has a varying current is the output transistor. I.e. all the other transistors are biased by constant current sources.

- Fig. 5 shows three embodiments for symmetrical input bias resistors. The
- 25 first one is common known and has proven to work well. It consists of two cross coupled diodes. The impedance/resistance arround zero biasing is very high and at typically 400mV-600mV the device starts to clamp the signal. I.e. the impedance drops dramatically. Implementation no 2 is two crosscoupled bipolars. And implementation no 3 is basically an implementation of two
- 30 crosscoupled diodes using mos devices instead. Which one to use depends on avaiability of technology and demands. I.e. the simplest two crosscoupled

- diodes has proven to work well. The impedance is very high a zero biasing and it clamps the signal for large levels as it should. The impedance is though is some processes too large (examples of upto 100T ohms has been measured) and the clamping of the signal happens very often happen at to
- 5 low signal levels. In that case the other two solutions might prove better. Especially the two MOS devices. One can make new symmetrical high impedent devices by coming any of the three implementations.
- 10 Figure 6 shows the preamplifier with RF filters implemented. With today's widespread use of mobile phones, microphones are exposed for very powerfull high frequency signals. E.g. The RF GSM signal of a mobile phone. And especially a microphone for a mobile is exposed to very large RF signals as it is located very close to the antenna. It is well know that nonlinearities in
- 15 semiconductors can intermodulate low frequency variation of RF signals into the low frequency bandwidth. E.g. A GSM phone is transmitting with a periode of 217Hz. If by example a diode is exposed to a GSM signal then the nonlinearity of the diode together with the GSM signal will create a very powerfull 217 Hz component and harmonics of this. One of the most efficient
- 20 ways of reducing this problem is to simply prevent the GSM signal to reach the nonlinear semiconductor components. This can be done by adding filters on every connection pad for the amplifier ASIC. This is shown in figure 6. This approach is very effective but the problem is that these filters besides of filtering the RF noise out they also affect the performance of the amplifier.
- 25 I.e. output impedance increases, noise increases etc. But in the case of a feedback amplifier this problem is greatly reduced as the overall performance of the amplifier is greatly determined by the FB- filter and by the input stage. So if the high frequency components can be prevented to access the inputstage then the feedback loop will by itself suppress lowfrequency
- 30 intermodulated introduced elsewhere in the amplifier. And the amplifier will because of typically a high openloop gain have a performance which is

unaffected even though very effective RF filters are added to the output pads/connections. On the input also Rf filters can be added but here the noise of these are not suppressed by the loopgain. But as the overall amplifier structure has lower noise thus this can be traded off for a more

5 effective RF filter on the input.

Figure 7 shows preamplifier and feedbackfilter with DC offsets implemented in both. The purpose of the DC offset is to set the DC bias voltage of the output of the amplifier. A DC offset implemented in the amplifier will be

10 amplified by the DC closed loop gain of the amplifier thus setting the output DC level of the amplifier. In order to handle lowfrequency signals and external offsets on the input the DC offset of the amplifier will have to be designed for a fairly large value. Which can be a problem when optimizing for lowest possible noise. And also when optimizing for lowest possible area. I.e.

15 lowest cost.

More optimal is it to implement the offset in or just after the FB-filter. In this way the offset will not be multiplied by the DC closed loop gain of the amplifier and also the amplifier can be designed for lower noise without

20 increasing the area. It can though be a problem to implement all off the offset in the filter so a combination of an offset in the amplifier and an offset in the feedback filter will normally prove to be optimal.

Figure 8 shows openloop amplifier gain (curve # 1), typical filter

25 transferfunction (curve #2), typical loopgain (curve #3) and overall transferfunction of the amplifier in a feedback configuration using the feedback filter shown in curve # 2. The figure is an principle figure of the transferfunctions.

The openloop amplifier gain (curve #1) is the wellknown dominating pole type with a single dominating pole located at frequency F1 and a very large gain at low frequencies.

- 5 The feedback filter (curve # 2) in its simplest form consists of one pole and one zero. The pole being located at a lower frequency than the zero. Basically the filter has a low frequency region and a higher frequency region with a lower gain than the low frequency region.
- 10 The combination of the the openloop gain and the feedback filter shows the loopgain (curve # 3) and it can now be seen easily that the loopgain is very large below frequency F2 where the overall transferfunction (curve # 4) of the amplifier in a feedback configuration using the feedback filter shown in curve # 2.

15

Figure 9 shows the amplifier in a configuration with a voltage pump. A voltage pump is typically needed when there is no charged electret layer in the microphone. E.g. A silicon microphone. In this case an external bias is needed and can be supplied by a voltage pump. Voltage pumps are normally quite noisy and thus a decoupling filter is needed. This filter can consist of a decoupling cap and a large resistor. To decouple the noise of the voltage pump a filter with a very low cutoff is needed. And thus it settles very slowly during power up. I.e. a very large low frequency signal will be present on the input of the amplifier. So the solution of designing an amplifier with a low gain at low frequencies again proves to be very beneficial.

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Generally, it should be noted that embodiments of the invention may comprise one or more of the described features. For instance, the preamplifier may comprise one or more of the following features:

30

- A DC offset in the preamplifier stage;
- A DC offset in the feedback filter;

- A DC offset in both the preamplifier stage and the feedback filter;
- A voltage pump;
- A voltage pump in combination with a DC offset;
- A radio frequency, RF, filter coupled to the following circuit nodes:
 - 5 ○ a non-inverting amplifier input; and/or
 - an inverting amplifier input; and/or
 - a filter input; and/or
 - an amplifier output.
- An input bias element.

10 It should be noted that the invention is not limited to the disclosed embodiments.

The above features may be applied in embodiments of a preamplifier configuration that comprises a gain stage with a feedback filter, where the configuration has a relatively low gain response for frequencies below an
 15 audio band and has a relatively high and substantially flat gain response in the audio band. The audio band can be defined to be any band within the typical definition of an audio band. A typical definition can be 20Hz to 20KHz. Exemplary lower cutoff frequencies for an audio band can be: 20 Hz, 50Hz,
 20 80 Hz, 100Hz, 150 Hz, 200Hz, 250hz. Exemplary upper cutoff frequencies the an audio band could be 3KHz, 5KHz, 8KHz, 10KHz, 18KHz, 20KHz. By substantial flat is meant gain response variations within approximately +/-
 1dB; +/-3dB; +/-4dB; +/-6dB. However, other additional values of variation can be used to define the term 'substantial flat'.

CLAIMS

1. A microphone preamplifier which provides an output signal in response to an input microphone signal and an input feedback signal obtained by filtering the output signal with a filter.
2. A microphone preamplifier according to claim 1, comprising a differential input stage with an inverting input and a non-inverting input, wherein the non-inverting input is arranged to receive the microphone signal, and the inverting input is arranged to receive the feedback signal.
3. A microphone preamplifier according to claim 1, wherein the filter has a transfer function, in the frequency domain, with a zero and a pole; wherein the zero is located at a higher frequency than the pole.
4. A microphone preamplifier according to claim 1, wherein the preamplifier has a transfer function, in the frequency domain, with a zero and a pole; wherein the pole is located about 0.2-200 Hz.
5. A microphone preamplifier according to claim 1, wherein the filter, in the frequency domain, has a relatively high gain level below a transition frequency range and a relatively low gain level above the transition frequency range.
6. A microphone preamplifier according to claim 5, wherein the transition frequency range is located below a frequency of 50 Hz.
7. A microphone preamplifier according to claim 5, wherein the transition frequency range is located below a frequency of 100 Hz.

8. A microphone preamplifier according to claim 1, wherein the filter is an active filter.

5 9. A microphone preamplifier according to claim 1, wherein the filter is a passive filter.

10 10. A microphone preamplifier according to claim 1, wherein the output signal from the preamplifier is made available on a terminal to which the preamplifier is coupled to receive power supply.

11. A microphone preamplifier according to claim 1, wherein the preamplifier is configured to receive the microphone signal via an input bias element which has relatively high ohmic impedance when the microphone signal is relatively small in magnitude and relatively low ohmic impedance when the microphone signal is relatively high in magnitude.

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12. A microphone preamplifier according to claim 11, wherein the bias element is configured by two cross-coupled diodes.

20 13. A microphone preamplifier according to claim 11, wherein the bias element is configured by two cross-coupled bipolar transistors.

14. A microphone preamplifier according to claim 11, wherein the bias element is configured by two cross-coupled Metal Oxide Semiconductor, MOS, devices.

25

15. A microphone module comprising:
an electret microphone; and
a preamplifier configured to provide an output signal in response to an input
30 signal from the electret microphone and an input signal obtained by filtering the output signal.

16. A microphone module according to claim 15 wherein the electret microphone is mounted in a cartridge and the preamplifier is integrated in the microphone module.

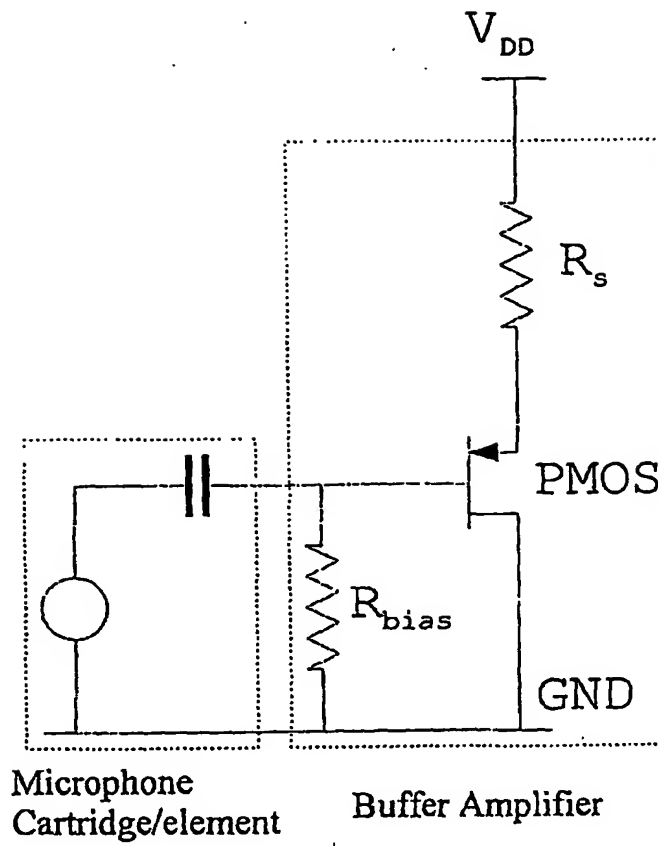
ABSTRACT

The invention relates to a microphone preamplifier which provides an output signal in response to an input microphone signal and an input feedback signal obtained by filtering the output signal with a filter.

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Additionally, the invention relates to a microphone module.

(fig. 3 should be published)

*Fig. 1*

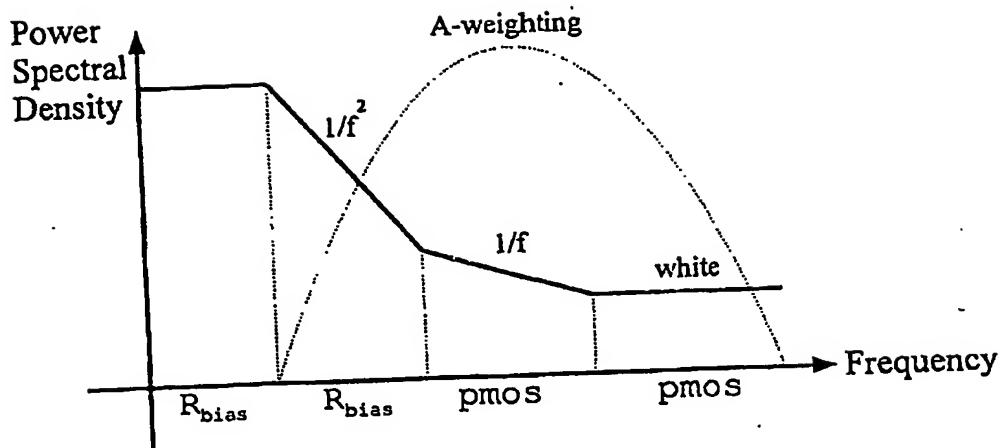
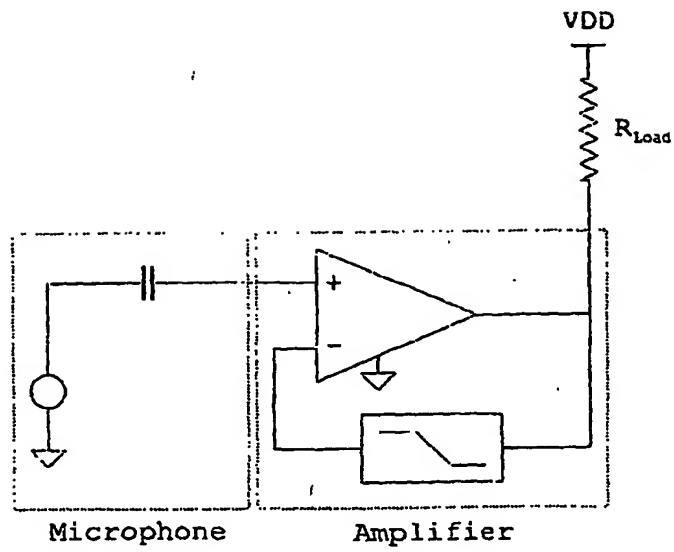
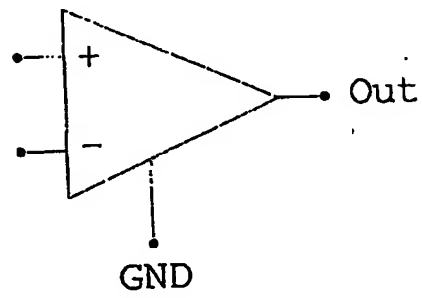
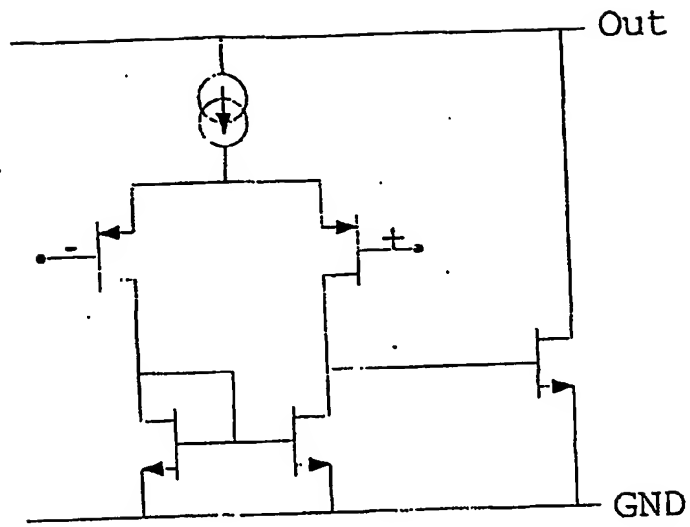


Fig. 2

*Fig. 3*

*Fig. 4*

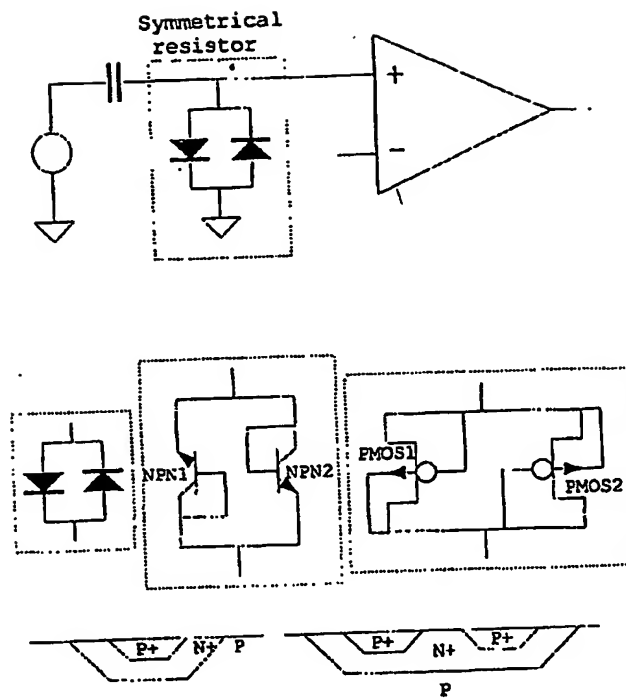


Fig. 5

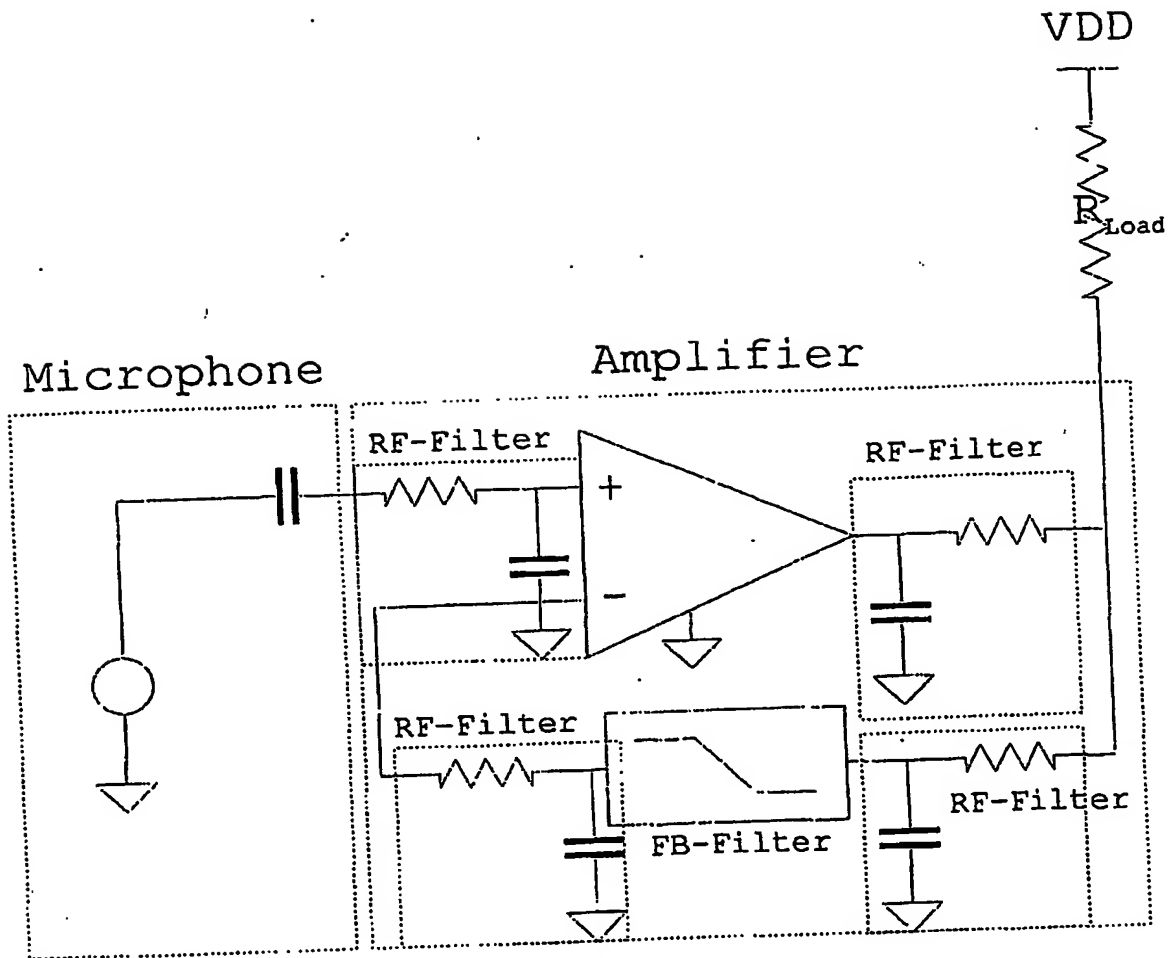


Fig. 6

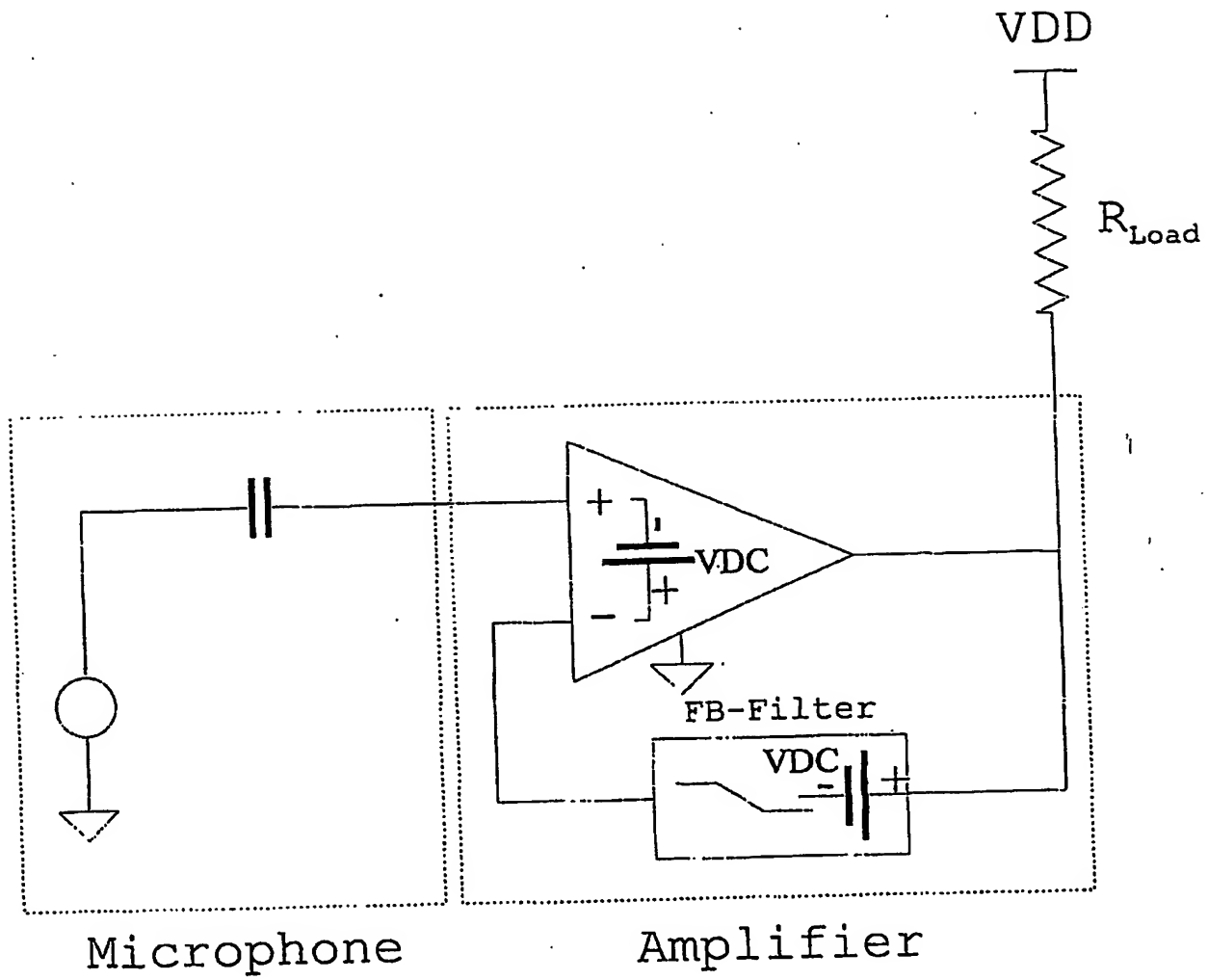
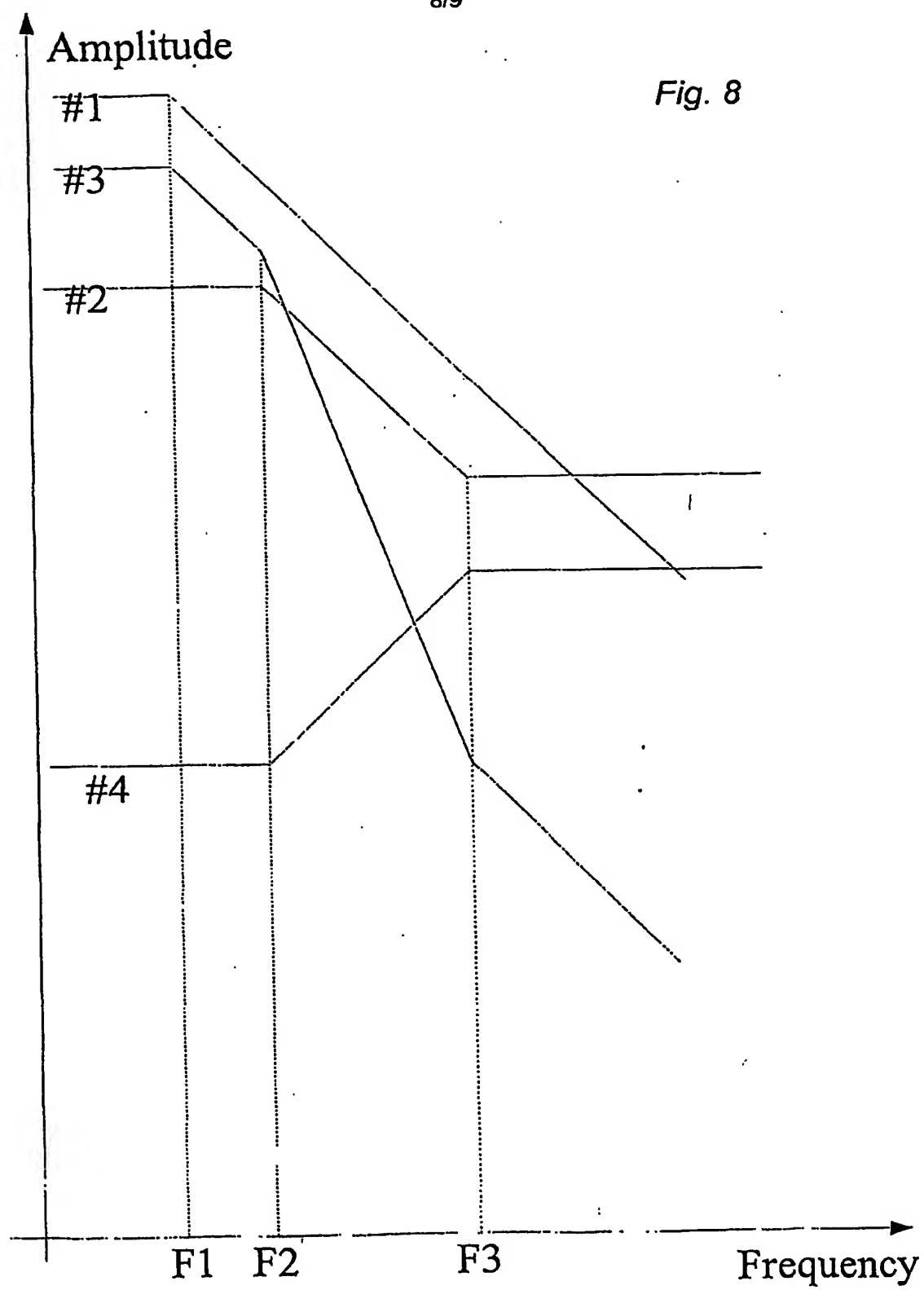


Fig. 7



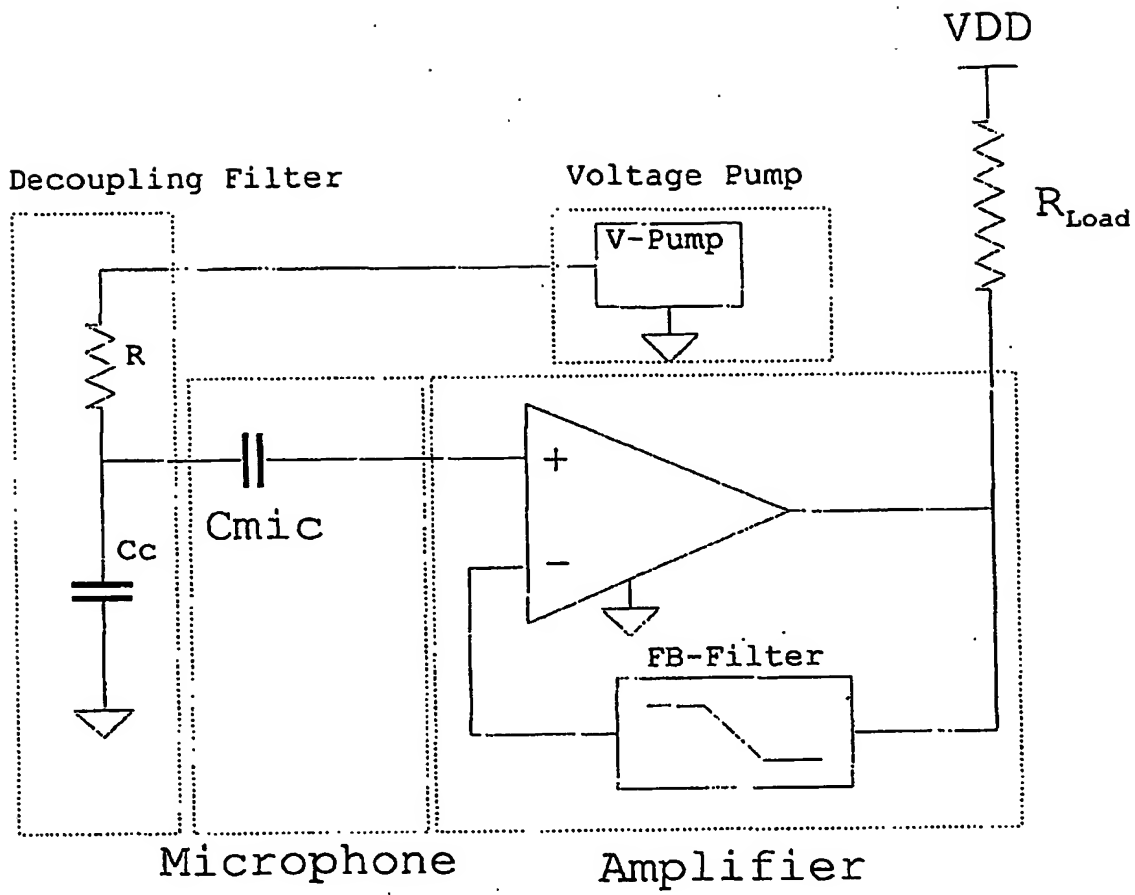


Fig. 9

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